CD-MRW

Defect Management
&
Physical Formatting

version 1.2

June 2004

Compaq Computer Corporation
Microsoft Corporation
Royal Philips Electronics
Sony Corporation

Confidential

Compact Disc Mount Rainier ReWritable

Defect Management & Physical Formatting

Version 1.2

June 2004

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I General

I.1 Scope

This document defines methods for Defect Management and Physical Background Formatting that can be applied to CD-RW. Applying the procedures and formats described in this document will improve the performance of the CD-RW system in a computer environment.

I.2 Main features

A CD-MRW system according to the specifications in this document will offer the following features:

- full random access,
- Defect Management handled by the drive (or by a dedicated Read-Only device driver),
- Physical formatting performed in background by the drive (without interaction with the host computer),
- the disc will be available for use immediately after insertion,
- ejecting the disc before the Background Formatting process is completed is possible,
- the disc is a Single-session disc, with a single Data Track,
- the Data Track is divided in fixed Packets of 32 User Data Blocks,
- the data transfer between host computer and drive is based on 2K User Data Blocks,
- recorded discs will be compatible with MultiRead compliant CD-ROM drives.

I.3 References and conformance

CD-MRW Defect Management and Physical Formatting conforms to the mandatory requirements specified in this document (referred to as DM&PF). All parts in this document are mandatory unless they are specially defined as recommended or optional or informative.
CD-MRW Defect Management and Physical Formatting can be applied to CD-RW discs according to the Orange Book, part III, volume 1 or volume 2.

Note:
Due to advances in technology and market requirements, System Descriptions might need to be extended after some time. This could mean that new items, such as e.g.: new modes, new pointers, new formats, new data structures or definitions for reserved bits/bytes, may have to be added to a System Description.
System designers should take notice of this in the design of their products (e.g. check for version numbers).

CD-MRW also conforms to the applicable parts of the System Descriptions or international standards that are listed below:

- CD-RW, volume 1: Compact Disc ReWritable, specified in the System Description Recordable Compact Disc Systems, part III: CD-RW, volume 1: 1x/2x/4x ("Orange Book"), Royal Philips Electronics and Sony Corporation.

- CD-RW, volume 2: Compact Disc ReWritable, specified in the System Description Recordable Compact Disc Systems, part III: CD-RW, volume 2: High-Speed ("Orange Book"), Royal Philips Electronics and Sony Corporation.

- CD-DA: Compact Disc Digital Audio, specified in the System Description Compact Disc Digital Audio ("Red Book"), Royal Philips Electronics and Sony Corporation.

- CD-ROM: Compact Disc Read Only Memory, specified in the System Description Compact Disc Read Only Memory ("Yellow Book"), Royal Philips Electronics and Sony Corporation.
- CD-ROM XA: Compact Disc Read Only Memory eXtended Architecture, specified in the System Description CD-ROM XA, Royal Philips Electronics and Sony Corporation.
- CD-logos: CD Logo Guide Royal Philips Electronics
- “MultiRead”: MultiRead Specifications for CD-ROM, CD-R, CD-R/RW and DVD-ROM Devices, Optical Storage Technology Association (OSTA)
- ISO 646: Information processing ISO 7-bit coded character set for information interchange. Ref. No. ISO 646 : 1983 (E).
- ISO 9660: Information processing Volume and file structure of CD-ROM for information interchange. Ref. No. ISO 9660 : 1988 (E).
- “El Torito”: Bootable CD-ROM Format Specification, version 1.0, January 25, 1995 Phoenix Technologies and IBM

I.4 Conventions and notations

I.4.1 Meaning of words

In this document the following words have a special meaning:

May: indicates an action or feature that is optional.

Optional: describes a feature that may or may not be implemented.
If implemented, the feature shall be implemented as described.

Shall: indicates an action or feature that is mandatory and must be implemented to claim compliance to this specification.

Should: indicates an action or feature that is optional, but its implementation is strongly recommended.

I.4.2 Representation of numbers

Numbers in decimal notations are represented by the digits 0 to 9. The decimal symbol is "." (dot). In large numbers the "," (comma) can be used as digit grouping symbol.

Numbers in hexadecimal notation are represented by the hexadecimal digits 0 to 9 and A to F followed by lowercase "h". The character x in hexadecimal numbers represents any digit 0 to 9 or A to F.

Numbers in binary notations and bit patterns are represented by strings of digits 0 and 1 followed by lowercase "b", with the most significant bit shown to the left. The character x in binary numbers represents a digit 0 or 1.
Negative values of numbers in binary notation are given as Two's complement.
In a pattern of n bits, bit $b_{[n-1]}$ shall be the most significant bit (msb) and bit b_0 shall be the least significant bit (lsb). Bit $b_{[n-1]}$ shall be recorded first.

In each data field, the data is recorded so that the most significant byte (MSB), identified as Byte 0, shall be recorded first and the least significant byte (LSB) last.
In a field of 8n bits, bit $b_{[8n-1]}$ shall be the most significant bit (msb) and bit b_0 the least significant bit (lsb). Bit $b_{[8n-1]}$ shall be recorded first.

A range of values is indicated as x ~ y, where x and y are included in the range.
A list of integers is indicated as i..j. The list contains all numbers between i and j, including i and j (e.g. k = 0..3 means: k can adopt the values 0, 1, 2 or 3).
If the step size is different from 1, this is indicated as: i, [i+s]..j (e.g. k = 1, 4..16 means: k can adopt the values 1, 4, 7, 10, 13 or 16).
A group of parameters is indicated as Param m..n or P_m .. P_n. The group contains all parameters with an index between m and n, including m and n (e.g. byte 16..31, bit 7..4, Add_0 .. Add_{255}).

I.4.3 Names

The names of entities, e.g. specific tracks, fields, etc., are given with an initial capital.

I.5 Definitions

I.5.1 Definitions of terms

ATIP time code	:	The blank CD-RW disc has a wobbled Pre-groove for tracking and addressing purposes. The wobble is frequency modulated with a time code.
Blank	:	see unrecorded area
Block	:	A unity of 2352 bytes as defined in the Yellow Book (page 100). In general 2048 bytes of the Block are data bytes. The other bytes are used for synchronization, addressing and error correction/detection.
Finalization	:	The action in which (partially) unrecorded or logically erased tracks are finished and the Lead-in and/or Lead-out Areas are recorded or overwritten with the appropriate TOC subcode.
Ice	:	see unrecorded area
MSF addressing	:	The basic CD addressing mode, based on the time code in the Subcode. This time code consists of Minutes, Seconds and Frames.
Multisession disc	:	A disc that contains or can contain more than one Session (in each Lead-in Area the start time of the next Program Area is indicated in mode 5 of the subcode Q-channel).
Packet	:	The smallest amount of information that can be recorded independently. A Packet consists of a Link Block, 4 Run-in Blocks, N User Data Blocks and 2 Run-out Blocks. The Packet size is N. See CD-RW volume 1 & 2, chapter V.2.3.
Recorded Information	:	Information, stored as marks on the disc during the recording or overwrite process of the CD-RW disc.
Reserved	:	"Reserved" in relation to a value means: the specified value(s) shall not be used. In future standards, these value(s) can be assigned. "Reserved" in relation to a field means: the use of the field(s) is not specified and the value(s) in the field(s) must be set to zero, unless specified otherwise. In future standards, the use of these fields can be defined. Drives compliant with any version of this document shall ignore fields and values that were Reserved in the version of the document according to which the drive has been designed, but which fields and values have been assigned in more recent versions.
Session	:	An area on the disc consisting of a Lead-in Area, a Program Area and a Lead-out Area.

Single Session disc	:	A disc containing one Session (in the Lead-in Area the start time of the next Program Area indicated in mode 5 of the subcode Q-channel shall be set to FF FF FFh).
Subcode	:	A separate data channel, composed from an additional byte in each EFM frame, used to store complementary information such as e.g.: Track number, address (time code), pause indication, text. See Red/Yellow Book.
TDB	:	**T**rack **D**escriptor **B**locks in the Pre Gap of a data Track contain information about the Track attributes. (see CD-RW volume 1 & 2, chapter V.6.5)
TOC	:	**T**able **O**f **C**ontents: in the Lead-in Area the subcode Q-channel contains information about the Tracks on the disc.
Track	:	A contiguous area on the disc, identified by one and the same Track number.
Unrecorded area	:	An area in which no signal has been recorded, or in which a previously recorded signal has been physically erased. The track (groove) is in the high-reflective state, also called “ice” or “blank”.
User-recorded area	:	An area (or Track) recorded with an EFM signal containing user data and normal Subcode Q (not mode 0).
User Data Block	:	A Block containing 2K of user data (see Block).
Write_streaming	:	A method of recording real-time data (such as digital video).

I.5.2 List of acronyms

acronym	meaning
ATIP	Absolute Time In Pre-groove
BP	Byte Position
DA	Data Area
DM&PF	Defect Management & Physical Formatting (as reference to this document)
DOW	Direct OverWrite
DM	Defect Management
DTB	Defect Table Block
FSS	File System Structure
GAA	General Application Area
LBN	Logical Block Number
LI	Lead-In area
LO	Lead-Out area
LSB	Least Significant Byte
lsb	least significant bit
LVA	Last Verified Address
LWA	Last Written Address
MDT	Main Defect Table
MIP	Main Information Packet
MSB	Most Significant Byte
msb	most significant bit
MSF	Minutes:Seconds:Frames address
MTA	Main Table Area
OPC	Optimum Power Control
OS	Operating System
PBN	Physical Block Number
PTP	Progress Tracking Pointer
RO	Read-Only
RSV	Reserved
SA	Spare Area
SDT	Secondary Defect Table
SIP	Secondary Information Packet
STA	Secondary Table Area
TDB	Track Descriptor Block
TOC	Table of Contents
UD	User Data

II Introduction

Functionality

To exploit the full capabilities of CD-MRW in a computer data storage environment, several conditions should be fulfilled:

1) the system needs full random access,
2) the recorded discs shall be compatible with MultiRead compliant CD-ROM drives,
3) the system needs a method of Defect Management that can be handled by the drive or by a dedicated RO device driver,
4) physical formatting shall be performed by the drive in background without interaction with the host computer,
5) the disc should be available for use immediately after insertion,
6) the time to eject the disc shall be minimal,
7) recording shall be based on fixed Packets of 32 User Data blocks, in a single Track, on a Single-session disc,
8) the data transfer between host computer and drive shall be based on 2K data blocks.

Compatibility

To guarantee read compatibility with MultiRead CD-ROM drives (or CD-R/RW recorders not compliant with this DM&PF), the following requirements have to be fulfilled:

- the disc shall have a Lead-in Area, a Program Area and a Lead-out Area,
- all Program Area between the Lead-in Area and the Lead-out Area shall be fully physical formatted,
- all data, including the Defect Management information and Replacement Areas shall be available inside the Program Area (the original logically addressable space) of the disc (see Figure 1). The Defect Management then could be handled also by a dedicated RO device driver running in the host computer.

When a disc fulfils all these conditions, we call such a disc: **"ROM-compatible"**.

To facilitate the use of the disc by CD-ROM drives that do not support Defect Management, optional RO device drivers, which can add this functionality to the system, could be recorded on the disc.

Defect Management

The Defect Management system is based on a Main Table Area (MTA), a Secondary Table Area (STA) and Spare Areas (SA) equally distributed over the Program Area of the disc. As well the SA's as the DA's in between the SA's have a fixed number of Packets.
The Main Table Area is located at the end of the Lead-in Area of the disc, the Secondary Table Area is located at the end of the Program Area (see Figure 1).

Formatting

Generally the end-user of the system likes to have the disc ready for use within seconds after it has been inserted into the drive. A blank disc however has to be physical formatted before all it's capabilities can be exploited fully. Because the normal physical formatting process significantly delays the use, a background formatting procedure will be defined that initializes the disc with a minimum amount of information, after which it is available for recording. The Background Formatting process proceeds with the physical formatting during the time intervals when the drive is idle. The Background Formatting described in this document only defines the physical formatting of the disc, which is file-system independent.
A fully physical formatted disc is always in a ROM-compatible state. In this state, an eject command can be executed without delay.
When an eject is requested before the disc has been fully physical formatted, a quick finishing process shall be executed to make the disc ROM-compatible before it leaves the recorder.

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III Logical disc format

III.1 Basic lay-out of the disc

Recorders, compliant with this DM&PF, shall be able to access Defect Management information located in the Lead-in Area.
Devices not compliant with this DM&PF are in general only able to address the Program Area of the disc. Therefore, for reasons of compatibility with these types of devices, the Secondary Table Area and the Spare Areas are recorded in the Program Area of the disc.
Additionally a General Application Area (GAA) has been defined, which can be used to further facilitate compatibility with non-compliant devices.
The Lead-in Area contains the Main Table Area, to be used by recorders.

The general lay-out of the disc shall be as defined in Figure 1.

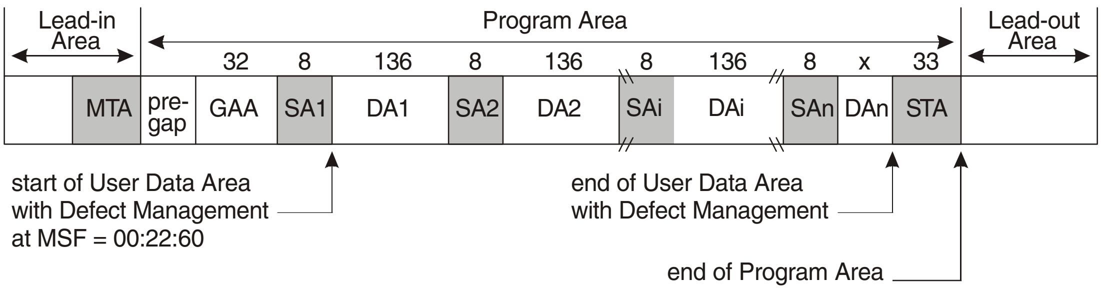

Figure 1 Basic disc lay-out

The pre-gap has a fixed size of 150 Blocks and shall be recorded according to the rules as specified in the CD-RW System Description, volume 1 or volume 2.

The General Application Area (GAA) shall consist of 32 Packets.

Each Spare Area SA shall consist of 8 Packets.

Each Data Area DA shall consist of 136 Packets, except for the last one (DAn), which is allowed to be ≤ 136 Packets to fit to the available capacity of the disc.

Note: It is not allowed to end with an SA of less than 8 Packets. In this case the start of the actual Lead-out Area shall be set to a lower time code value (less than the maximum indicated in ATIP) such to adapt the nett capacity of the disc.

The Secondary Table Area shall consist of 33 Packets.

The Main Table Area has a variable size.

III.1.1 General Application Area

The GAA shall contain a basic File System Structure (FSS) compliant with all CD-ROM systems. This FSS can point to bootable programs, special drivers, or URL addresses from where drivers can be downloaded to make a system “Read-compatible” with the format described in this document. For further explanations see annex VI.1.

III.1.2 Main Table Area

The MTA is meant to store the Defect Tables generated by CD recorders compliant with this DM&PF. Because the Packets in the MTA may be overwritten many times, the Defect Management system can assign substitute MTA Packets backwards into the Lead-in Area. This guarantees sufficient replacement areas for Defect Tables over the life span of the disc.

III.1.3 Secondary Table Area

The STA is meant to be used for Defect Management during read-out by CD-ROM drives and CD recorders, not compliant with this DM&PF. It is also a back-up in cases of failures in the MTA.
At eject of the disc, the information contained in the STA shall be equivalent to the information contained in the MTA.

III.1.4 Spare Areas and Defect Management capacity

The size of the Spare areas and the Data Areas is fixed. Therefore the total number of Replacement Packets is depending on the capacity of the disc.
The spare capacity is always about 8/(136+8) = 5.5%.

Example 1: 74 minutes disc
last possible start time of Lead-out Area indicated in the wobble of the disc:
74min:01sec:13frames
The User Data capacity of this disc = 58∗136+112 = 8000 Packets (**500 Mbytes**; M = 2^{20})

pre-gap	GAA	SA1/DA1	SA2/DA2	...		SA59/DA59	STA	Lead-out
150 Blocks	32 Packets	8+136 Packets	8+136 Packets	...	8+136 Packets	8+112 Packets	33 Packets	--
	(first 5 Blocks in pre-gap)	58 ∗ 144 Packets				120 Packets		actual start of LO = 74:01:13

Example 2: 80 minutes disc
last possible start time of Lead-out Area indicated in the wobble of the disc:
79min:59sec:74frames (maximum capacity of CD-RW)
The User Data capacity of this disc = 63∗136+82 = 8650 Packets (**540 Mbytes**; M = 2^{20})

From this example we see that the **maximum number of Spare Areas can be 64**.

pre-gap	GAA	SA1/DA1	SA2/DA2	...		SA64/DA64	STA	Lead-out
150 Blocks	32 Packets	8+136 Packets	8+136 Packets	...	8+136 Packets	8+82 Packets	33 Packets	--
	(first 5 Blocks in pre-gap)	63 ∗ 144 Packets				90 Packets		actual start of LO = 79:59:73

Example 3: 22 minutes disc (8 cm)
last possible start time of Lead-out Area indicated in the wobble of the disc:
22min:20sec:06frames
The User Data capacity of this disc = 17∗136+52 = 2364 Packets (**147 Mbytes**; M = 2^{20})

pre-gap	GAA	SA1/DA1	SA2/DA2	...		SA18/DA18	STA	Lead-out
150 Blocks	32 Packets	8+136 Packets	8+136 Packets	...	8+136 Packets	8+52 Packets	33 Packets	--
	(first 5 Blocks in pre-gap)	17 ∗ 144 Packets				60 Packets		actual start of LO = 22:19:67

III.2 Linking

Recording on CD-MRW discs is performed in Packets, which Packets shall be linked together by means of 2 Run-out Blocks, a Link Block and 4 Run-in Blocks. Figure 2 shows details of the Linking in the Program Area. The Program Area consists of one Track with fixed Packets with a size of 32 User Data Blocks.

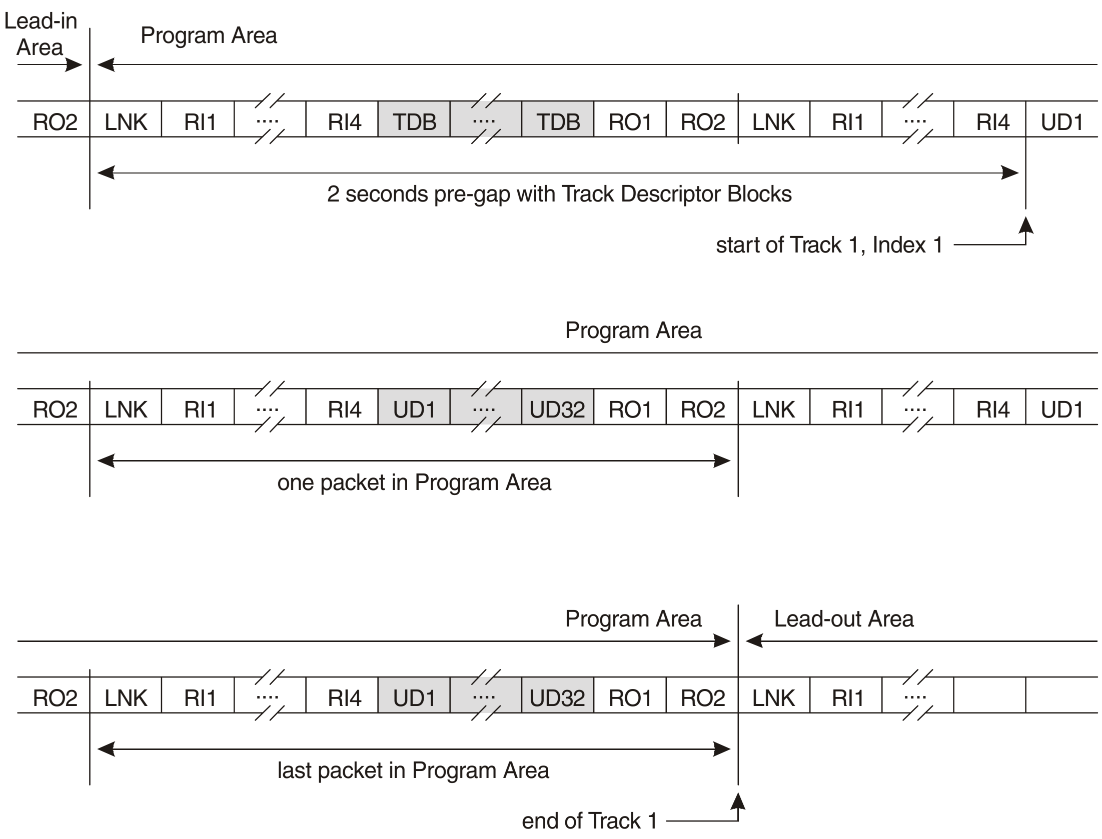

Figure 2 Linking details of Program Area

LNK = Link Block
RI1 .. RI4 = Run-in Blocks
RO1, RO2 = Run-out Blocks

UD1 .. UD32 = User Data Blocks
TDB = Track Descriptor Block

III.3 Data mode

All data on the disc shall be written in Mode 2 / Form 1.
(see System Description CD-ROM XA: for this version of the DM&PF the subheader field shall be set to all 00h. In future versions other settings might be defined).

III.4 Addressing Methods

For the addressing of the data written on the disc, two basic methods are defined:

- The Defect Management system and certain special utilities need easy access to the whole Program Area (including the GAA, SA's and STA) and the MTA. For the addressing of these contiguous areas, a Physical Block Numbering (PBN) is defined. These PBN's are equivalent to **addressing Method 2** according to the CD-RW System Description.
- Applications need easy access to the User Data Areas only. For the addressing of these interrupted Data Areas a new Logical Block Numbering (LBN) is defined. This LBN addressing is called **addressing Method 3**.

Finally the drive needs the MSF address to physically access the data. The MSF address in the Program Area can be calculated from an Absolute Block Number (ABN), which numbers represent all Blocks on the disc, starting from 0 at MSF 00:00:00, increasing by 1 for every next Frame, and including all disc areas (pre-gap, Link Blocks, Run-in Blocks and Run-out Blocks).
The MSF values can be calculated with the following formulas:

$$M = \mathrm{int}\left(\frac{ABN}{4500}\right),$$

$$S = \mathrm{int}\left(\frac{ABN}{75}\right) - 60 \times M, \text{ and}$$

$$F = ABN - 75 \times S - 4500 \times M \quad \text{for } ABN \geq 0.$$

III.4.1 PBN addressing (Method 2) for the whole Program Area + MTA

The Block numbers from the start of the Program Area up to and including the first User Data Block in the Track are calculated by:
PBN = (((MIN∗60)+SEC)∗75+FRAMES)-150
All the following PBN's are calculated by counting all User Data Blocks in all Packets in the Track. This means that all Run-in blocks, Run-out blocks and Link blocks are excluded (see attachment C8 of the CD-RW System Description, volume 1 or volume 2).
The result of this Block numbering is that the Blocks in the pre-gap have PBN –150 up to –1 (including the Link, Run-in and Run-out Blocks), the first User Data Block of the GAA has PBN 0, the first User Data Block of SA1 has PBN 1024, the first User Data Block of DA1 has PBN 1280, etc (see Figure 4).

The Absolute Block Numbers can be derived from the PBN with the following formula:

$$ABN = PBN + 150 + 7 \times \mathrm{int}\left(\frac{PBN}{32}\right) \quad \text{for } PBN \geq 0$$

In the MTA the addressing method is equivalent with Method 2 in the Program Area after the first User Data Block. All Run-in blocks, Run-out blocks and Link blocks are excluded from counting. All User Data Blocks in the MTA are numbered negative, such that the PBN of each next User Data Block towards the Program Area is increased by 1, ending with PBN -151 for the last User Data Block in the last Packet in the MTA (corresponding to MSF address 99:59:72, see Figure 3)

In the part of the Lead-in Area preceding the MTA and in the Lead-out Area no PBN's are defined.

disc area	packet/block	MSF	PBN
Lead-in Area	: :	: :	: x
	MDT1	99:58:38 : 99:58:69	-246 : -215
	RO, Link, RI	99:58:70.. 99:59:01	x
	MDT0	99:59:02 : 99:59:33	-214 : -183
	RO, Link, RI	99:59:34 .. 99:59:40	x
	MIP	99:59:41 : 99:59:72	-182 : -151
	RO	99:59:73 .. 99:59:74	x
Program Area	pre-gap	00:00:00 00:00:01 : 00:01:73 00:01:74	-150 -149 : -2 -1
	GAA packet 1	00:02:00 00:02:01 :	0 1 :

Figure 3 MSF and PBN addressing in the Lead-in Area
(x = skipped in counting)

III.4.2 LBN addressing (Method 3) for the User Data Areas only

In addressing Method 3 the Logical Block Numbers (LBN) are defined as follows:
LBN 0 is assigned to the first User Data Block in DA1.
All following LBN's are calculated by counting all User Data Blocks in the DA Packets in the Track. This means that all Run-in blocks, Run-out blocks and Link blocks, and all Spare Areas and the STA are excluded.
As a result the first User Data Block in DAi will have LBN (i-1)∗136∗32 = (i-1)∗4352 (see Figure 4).

The Absolute Block Numbers can be derived from the LBN with the following formula:

$$\mathrm{ABN} = \mathrm{LBN} + 150 + 7 \times \mathrm{int}\left(\frac{\mathrm{LBN}}{32}\right) + 39 \times \left[32 + 8 \times \left\{1 + \mathrm{int}\left(\frac{\mathrm{LBN}}{136 \times 32}\right)\right\}\right] \quad \text{for LBN} \geq 0$$

disc area	packet/block	MSF	ABN	PBN	LBN
Lead-in Area					
Program Area	pre-gap	00:00:00 00:00:01 : 00:01:74	0 1 : 149	-150 -149 : -1	x x x x
	GAA packet 1	00:02:00 : 00:02:31	150 :	0 : 31	x x x
	RO, Link, RI	00:02:32 .. 00:02:38	:	x	x
	GAA packet 2	00:02:39 : 00:02:70	189 :	32 : 63	x x x
	RO, Link, RI	00:02:71 ..	:	x	x
	:	:	:	:	x
	RO, Link, RI	.. 00:18:08	:	x	x
	GAA packet 32	00:18:09 : 00:18:40	:	992 : 1023	x x x
	RO, Link, RI	00:18:41 .. 00:18:47	:	x	x
	SA1 packet 1	00:18:48 : 00:19:04	:	1024 : 1055	x x x
	RO, Link, RI	00:19:05 ..	:	x	x
	:	:	:	:	x
	RO, Link, RI	.. 00:22:20	:	x	x
	SA1 packet 8	00:22:21 : 00:22:52	:	1248 : 1279	x x x
	RO, Link, RI	00:22:53 .. 00:22:59	:	x	x
	DA1 packet 1	00:22:60 : 00:23:16	:	1280 : 1311	0 : 31
	RO, Link, RI	00:23:17 ..	:	x	x
	:	:	:	:	:
	RO, Link, RI	.. 01:32:74	:	x	x
	DA1 packet 136	01:33:00 : 01:33:31	:	5600 : 5631	4320 : 4351
	RO, Link, RI	01:33:32 .. 01:33:38	:	x	x
	SA2 packet 1	01:33:39 : 01:33:70	:	5632 : 5663	x x x
	RO, Link, RI	01:33:71 ..	:	x	x
	:	:	:	:	x
	RO, Link, RI	.. 01:37:11	:	x	x
	SA2 packet 8	01:37:12 01:37:43	:	5856 : 5887	x x x
	RO, Link, RI	01:37:44 .. 01:37:50	:	x	x
	DA2 packet 1	01:37:51 :	:	5888 :	4352 :
	DAn packet x	: --:--:--	:	: ----	: ----
	RO, Link, RI	.. ..	:	x	x
	STA packet 1 : STA packet 33	--:--:-- : --:--:--	:	---- : ----	x x x
Lead-out Area					

Figure 4 MSF, PBN and LBN addressing in the Program Area
(x = skipped in counting)

IV Defect Management

IV.1 General

The Defect Management of a recorder replaces Blocks (2K), which are found to be defective during writing and/or reading. Because a recorder can only write complete Packets (each containing 1 Link Block, 4 Run-in Blocks, 32 User Data Blocks and 2 Run-out Blocks), replacing one Block means:
- reading the 32 User Data Blocks of a Replacement Packet,
- substituting the contents of a free Block in this Packet by the contents of the Defective Block and
- rewriting the complete Replacement Packet.

Detection of possible errors can be based on e.g. excessive servo signals, feedback from a “running OPC” during writing, or error flags from the error correction system during reading.

IV.2 Format of the MTA

The Main Table Area (MTA) contains:
- 1 Main Information Packet (MIP) and
- 8 Main Defect Table Packets (MDT0..7).
- The MTA may contain several invalid MDT Packets.

Figure 5 shows the lay-out of the MTA in the Lead-in Area.

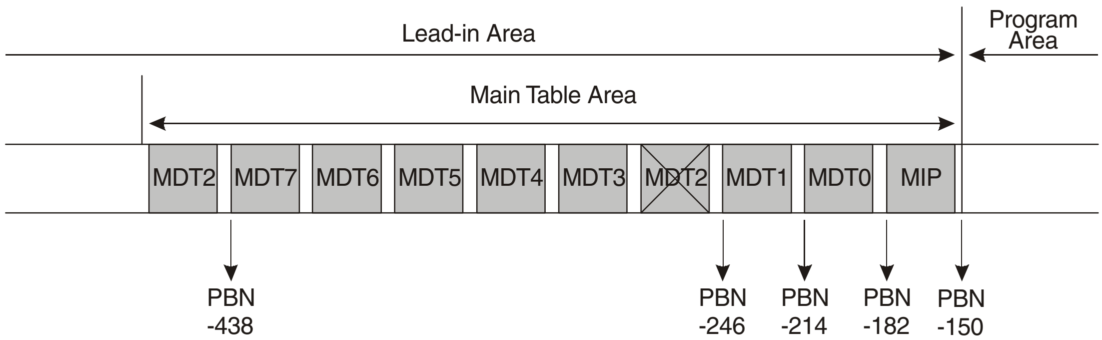

Figure 5 Basic lay-out of the MTA

The MIP shall be located at a fixed position. The first User Data Block of the MIP shall be located at PBN –182 (MSF 99:59:41).

The complete Defect List is contained in a maximum of 8 Packets (MDT0..7). The number of MDT Packets shall be at least such, that it is sufficient to store the locations of all Replacement Blocks in all Spare Areas that will be present on the finalized disc (see chapter IV.6.1). Whenever an MDT Packet becomes defective, a substitution Packet is created just preceding the leading Packet in the Lead-in Area (see Figure 5, where, as an example, MDT2 has been substituted). The locations of the valid MDT Packets are administrated in the MIP and the SIP.

IV.2.1 Linking in the Lead-in Area

Although the Lead-in Area will be formatted with variable Packet size (see chapter V.4), any Packet in the MTA in the Lead-in Area shall have a fixed size of 32 User Data Blocks and shall have the required Run-in and Run-out Blocks. See Figure 6. The area preceding the leading MDT Packet does not need to end with Run-out Blocks.

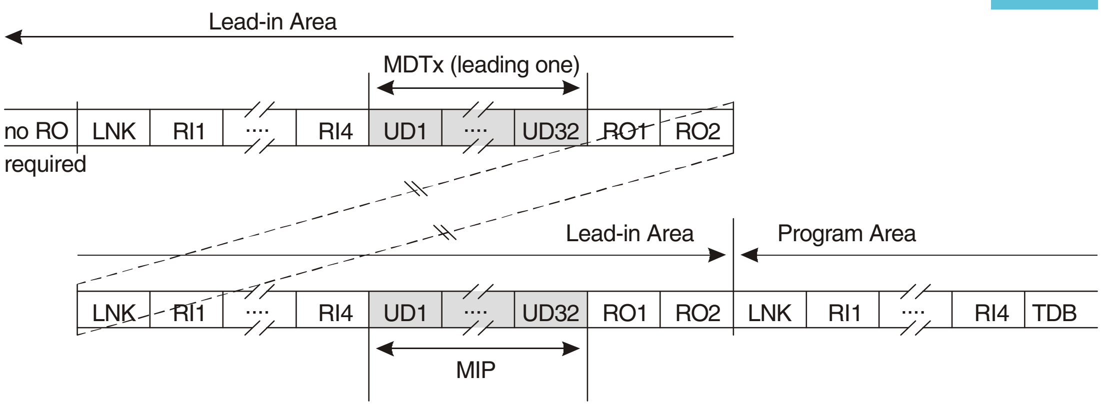

Figure 6 Linking details of Lead-in Area

IV.2.2 Continuity of subcode in the MTA

The time code in the subcode shall be continuous and synchronized to the ATIP time code according to the CD-RW System Description.
Inside the Packets, the TOC in the subcode shall be continuous and according to the CD-RW System Description. Crossing Packet boundaries, the TOC does not need to be contiguous.

IV.3 Format of the STA

The Secondary Table Area (STA) contains:
- 1 Secondary Information Packet (SIP) and
- 8 Secondary Defect Table Packets (SDT0..7).
- The STA may contain several invalid SDT Packets.

Figure 7 shows the lay-out of the STA.

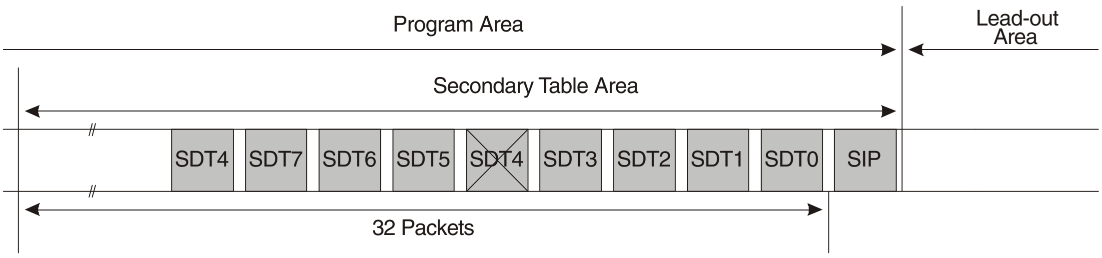

Figure 7 Basic lay-out of the STA

The SIP shall be located at a fixed position (the last Packet before the start of the Lead-out Area, with the first UD Block at MSF = actual start time of Lead-out – 00:00:34).

The complete Defect List is contained in a maximum 8 of Packets (SDT0..7). The actual number of SDT Packets shall be equal to the number of MDT Packets. Whenever an SDT Packet becomes defective, a substitution Packet is created just preceding the leading Packet in the Secondary Table Area (see Figure 7, where, as an example, SDT4 has been substituted). The locations of the valid SDT Packets are administrated in the MIP and the SIP.
All remaining Packets in the STA shall contain all AAh User Data bytes.

At eject of the disc, the information in each SDTi shall be made equivalent to the contents of MDTi.

IV.4 Format of the MIP and the SIP

The Main Information Packet (MIP) and the Secondary Information Packet (SIP) contain the basic information about the Defect Management structures on the disc. The Packets are always at a fixed location: the MIP at the end of the Lead-in Area, just preceding the Program Area, and the SIP at the end of the Program Area, as the last Packet before the Lead-out Area. All information in the MIP/SIP shall be contained in a 2K Block, which Block shall be repeated 32 times.
Logical (LBN) as well as Physical Block Numbers (PBN) shall be recorded in binary notation.
When problems occur with the retrieval of the information contained in the MIP or SIP, the disc should be mounted as a read-only disc (see annex VI.2).

BP in Block	Contents	Length in bytes
0	Signature of the MIP/SIP (“MIP” or “SIP”)	3
3	Format (4 msb’s) & Version (4 lsb’s) number	1
4	Version information for recorders for reading	1
5	Version information for recorders for writing	1
6	Reserved	2
8	MIP/SIP update count	4
12	Reserved	1
13	Last LBN in last Data Area (fully formatted)	3
16	Size of GAA = 32 Packets	2
18	Size of Spare Areas = 8 Packets	2
20	Size of Data Areas = 136 Packets	2
22	Reserved	2
24	Disc Status	1
25	Last Written Address (LWA) Pointer	3
28	Last Verified Address (LVA) Pointer	3
31	Number of MDT/SDT Packets in use (1..8)	1
32	Location of MDT0	3
…	…	…
32 + i∗3	Location of MDTi	3
…	…	…
53	Location of MDT7	3
56	Location of SDT0	3
…	…	…
56 + j∗3	Location of SDTj	3
…	…	…
77	Location of SDT7	3
80	Reserved	1968

Figure 8 Lay-out of the MIP/SIP Block

Byte 0..2: Signature

These 3 bytes shall be set to:
4D4950h, representing the characters “MIP”, in each Block of the MIP,
534950h, representing the characters “SIP”, in each Block of the SIP.

Byte 3: Format & Version number

The 4 most significant bits of this byte identify this CD-MRW format. They shall be set to 0000b. All other settings are reserved.
The 4 least significant bits of this byte specify the version number of the format, which number relates to the version number of this document. On discs compliant with this version of this document, these bits shall be set to 0001b.

Bytes 4..5: Version information
These 2 bytes indicate the compatibility of this disc with different recorder versions. They shall be set to 00h. All other values are reserved.

Byte 6..7: Reserved: these 2 bytes are reserved and shall be set to 00h.

Byte 8..11: MIP/SIP update count
These 4 bytes shall indicate the total number of update operations on the MIP. This field shall be set to 00000000h during the initial creation of the MIP, and shall be incremented by one each time the MIP is re-written. When the count reaches the value 4,294,967,295, the count shall wrap to 0 at the next update.
Whenever the contents of the MIP is copied to the SIP, the update count of the SIP shall be set to the same value as the update count of the MIP.

Byte 12: Reserved: this byte is reserved and shall be set to 00h.

Byte 13..15: Last LBN in last Data Area
These 3 bytes shall specify the last LBN (according to addressing method 3, see chapter III.4.2) in the last Data Area of the disc, reflecting the fully formatted situation.

Byte 13		**Byte 14**	**Byte 15**
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Reserved	*LBN of last User Data Block of fully formatted disc*		

Byte 16..17: Size of GAA
These 2 bytes indicate the number of Packets in the GAA as a binary value.
They shall be set to 0020h. All other values are reserved.

Byte 18..19: Size of Spare Areas
These 2 bytes indicate the number of Packets in each SA as a binary value.
They shall be set to 0008h. All other values are reserved.

Byte 20..21: Size of Data Areas
These 2 bytes indicate the number of Packets in each DA as a binary value.
They shall be set to 0088h. All other values are reserved.

Byte 22..23: Reserved: these 2 bytes are reserved and shall be set to 00h.

Byte 24: Disc status
This byte contains flags for indicating the status of the disc. They are used for tracking the Background Formatting process or the Verification process and for failure detection purposes.

Byte 24			
Bit 7..5	Bit 4	Bit 3..1	Bit 0
Formatting status	*Verification status*	*Reserved and set to zero*	*Used Disc*

Formatting status:
bit 7,6 = 00b : disc is not physical formatted,
01b : disc has been partially physical formatted;
in this case the LWA is indicated by bytes 25..27,
10b : disc has been fully physical formatted by the user,
11b : disc has been fully physical formatted by the manufacturer.

Bit 5 is meant to be used as a “De-icing not ready” flag (see chapter V.3).

bit 5 = 1b : indicates that the disc has been recorded non-consecutively, and that there are blank areas between some recordings.

0b : indicates that all Packets between the start of the Program Area and the last recorded User Data in the Data Area (see Figure 1) have been recorded or physical formatted.

Before ejecting a disc with bit 5 set to 1b, the blank area(s) shall be physical formatted and bit 5 reset to 0b.

Verification status:

bit 4 = 0b : no Verification in progress,

1b : Verification in progress;
in this case the LVA is indicated by bytes 28..30.

Used Disc:

Bit 0 is meant to be used as an indication that the Formatting process is running on a disc that originally was not blank, and thus still can contain obsolete information from a previous use.

This bit shall be set to 1b whenever a Formatting process is started on a non-blank disc. Whenever a write is requested to a non-verified area on a Used Disc, the drive shall perform a verify-after-write, except in case of a “write_streaming” command.

Byte 25..27: Last Written Address (LWA) Pointer

These 3 bytes are used by the recorder to store the address at which the Background Formatting process has been interrupted. It shall specify the first Physical Block Number (PBN) of the last Packet that has been recorded / physical formatted. Bit 7..4 of byte 25 are reserved and shall be set to zero.

Byte 25		**Byte 26**	**Byte 27**
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Reserved	*first PBN of last written Packet*		

Byte 28..30: Last Verified Address (LVA) Pointer

These 3 bytes are used by the recorder to store the address at which the Verification process has been interrupted. It shall specify the first Physical Block Number (PBN) of the last Packet that has been verified. Bit 7..4 of byte 28 are reserved and shall be set to zero.

Byte 28		**Byte 29**	**Byte 30**
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Reserved	*first PBN of last verified Packet*		

Byte 31: Number MDT/SDT Packets in use

This byte specifies the number of MDT/SDT Packets (1..8) that are actually in use (a Packet is defined to be in use if not all DT Entries are “Unused Entries”; see chapter IV.5.1).

Byte 32..55: Locations of MDTi

Each group of three bytes indicates the location of a valid MDT in the MTA in the Lead-in Area. The locations are defined by the first PBN of each MDT Packet.
Bit 7..4 of byte [32 + i∗3] are reserved and shall be set to zero.
For MDT's that are not present, these three bytes shall be set to FFFFFFh.

Byte [32 + i*3]		**Byte [32 + i*3 + 1]**	**Byte [32 + i*3 + 2]**
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Reserved	*first PBN of MDTi*		

Byte 56..79: Locations of SDTj

Each group of three bytes indicates the location of a valid SDT in the STA in the Program Area. The locations are defined by the first PBN of each SDT Packet.
Bit 7..4 of byte [56 + j∗3] are reserved and shall be set to zero.
For SDT's that are not present, these three bytes shall be set to FFFFFFh.

Byte [56 + j*3]		**Byte [56 + j*3 + 1]**	**Byte [56 + j*3 + 2]**
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Reserved	*first PBN of SDTj*		

Byte 80..2047: Reserved: these 1968 bytes are reserved and shall be set to 00h.

IV.5 Format of the Defect Tables (MDT and SDT)

Two types of Defect Tables are defined:
- the Main Defect Table (MDT), which shall be located in the MTA in the Lead-in Area,
- the Secondary Defect Table (SDT), which shall be located in the STA at the end of the Program Area.

The complete Defect Tables are contained in a maximum of 8 Packets: MDT0..7, with copies in SDT0..7. Each of the Packets MDTi or SDTi contain 4 repetitions of 8 2K-Blocks, in which the Defect Table information is stored. These 4 times 8 so-called Defect Table Blocks (DTB0..7) shall be interleaved as defined in Figure 9, which sequence gives a good protection against local defects on the disc (dust, scratches, etc.).

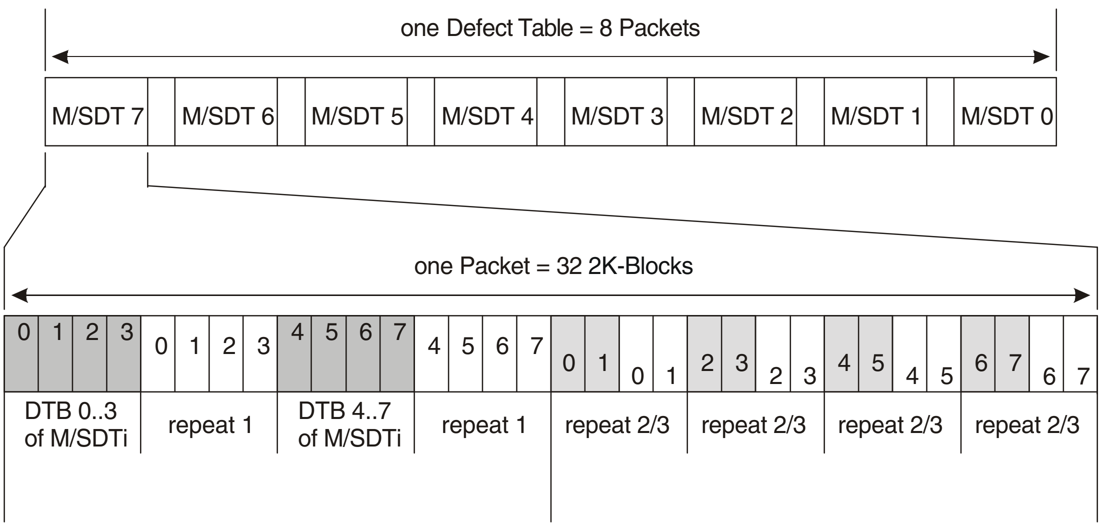

Figure 9 Composition of the Defect Tables

If not all DTB's in the last used MDT are needed, the remaining DTB's shall be formatted as empty DTB's. The first 32 bytes shall be filled in according to the rules defined in chapter IV.5.1. All remaining bytes (32..2047) shall be set to 00h.

All Packets of the SDT shall have the same contents as the corresponding Packets of the MDT (except for the Signature fields, but inclusive the update count fields).

IV.5.1 Lay-out of the Defect Table Blocks

Each Defect Table Block (DTB) contains a list of User Data Blocks, which have been determined to be defective during verification or during use of the media, and a list of Spare Blocks reserved for replacements. The defective User Data Block shall be linearly replaced by a reserved Spare Block as assigned in the Defect Table.

Each DTB shall have the contents as defined in Figure 10.
Physical Block Numbers (PBN) shall be recorded in binary notation.
Three basic types of Entries are defined:

- Entries that identify a defective Block to which a replacement Block has been assigned. These Entries are called: **Reallocation Entries**.
- Entries that identify a replacement Block that has not yet been assigned to a defective Block. These Entries are called: **Free Entries**.
- Entries that identify a replacement Block that can not be used, e.g. because the replacement Block itself is defective. These Entries are called: **Unusable Entries**.

BP in Block	Contents	Length in bytes
0	Signature of the MDT/SDT ("MDT" or "SDT")	3
3	MDT/SDT Packet number i (4 msb's) & Defect Table Block number k (4 lsb's)	1
4	MDT/SDT Packet update count	4
8	Number of DT Entries in this DTB (n)	2
10	Location of first Free Entry in this DTB	2
12	Location of first Unusable Entry in this DTB	2
14	Tables Status	1
15	Straight Mapping flag bits	1
16	Reserved	1
17	PBN of first Reallocation Entry in this DTB	3
20	Reserved	1
21	PBN of last Reallocation Entry in this DTB	3
24	Reserved	1
25	PBN of first Free Entry in this DTB	3
28	Reserved	1
29	PBN of last Free Entry in this DTB	3
32	DT Entry 1	6
…	…	…
32 + (n-1)∗6	DT Entry n (n ≤ 256)	6
32 + n∗6	Unused DT Entries (all bytes 00h)	1536 – n∗6
1568	Reserved	480

Figure 10 Lay-out of a Defect Table Block

Byte 0..2: Signature

These 3 bytes shall be set to:
4D4454h, representing the characters "MDT", in each Block of an MDT,
534454h, representing the characters "SDT", in each Block of an SDT.

Byte 3: MDT/SDT Packet number & Defect Table Block number

The 4 most significant bits of this byte specify the MDT/SDT Packet number i as a binary value. i = 0..7, other values are reserved.
The 4 least significant bits of this byte specify the Defect Table Block number k in the Packet as a binary value. k = 0..7, other values are reserved.

Byte 4..7: MDT/SDT Packet update count

These 4 bytes shall indicate the total number of update operations on this MDT Packet. This field shall be set to 00000000h during the initial creation of MDTi, and shall be incremented by one each time this MDTi is re-written. When the count reaches the value 4,294,967,295, the count shall wrap to 0 at the next update.
The update count field shall have the same value in all 2K-Blocks in one Packet.
Whenever the contents of the MDTi is copied to the SDTi, the update count fields of the SDTi shall be set to the same value as the update count fields of the MDTi.

Byte 8..9: Number of DT Entries

These 2 bytes shall indicate the total number of entries n in this DTB ($0 \leq n \leq 256$).

Byte 10..11: Location of first Free Entry

These 2 bytes shall point to the byte number in this DTB where the first Free Entry can be found (see chapter IV.5.1.2). If no Free Entries are available, bytes 10 and 11 shall be set to 0000h.

Note: the first Reallocation Entry is always located at byte 32, unless all Entries are free or unusable.

Byte 12..13: Location of first Unusable Entry

These 2 bytes shall point to the byte number in this DTB where the first Unusable Entry can be found (see chapter IV.5.1.2). If there are no Unusable Entries, bytes 12 and 13 shall be set 0000h.

Byte 14: Tables Status:

This byte contains flags for indicating the status of the Defect Tables. They are used for failure detection purposes.

Byte 14	
Bit 7..1	Bit 0
Reserved and set to zero	*Dirty Tables bit (in MDT0/SDT0 only; set to zero in MDT1..7 and SDT1..7)*

Dirty Tables bit:

Bit 0 of byte 14 is meant to be used as a “Dirty Tables” flag.

Bit 0 of byte 14 shall be set to 1b in all DTBs in MDT0 and SDT0, preceding the first update of any of the MDT0..7 Packets.

Bit 0 of byte 14 in all DTBs in SDT0 shall be reset to 0b, whenever all updated MDTs are copied to the related SDTs. After such an update of the SDTs, bit 0 of byte 14 in all DTBs in MDT0 shall be reset to 0b.

At “power-on” after a “bad power-down” (Dirty Tables bit = 1b in MDT0), the SDTs shall be updated.

Bit 0 of byte 14 in all DTBs in MDT1..7 and SDT1..7 shall be 0b.

Byte 15: Straight Mapping flag bits (see chapter IV.6.1)

Each single bit k (k = 0..7) of this byte reflects the mapping status of one of the DTB's within this MDTi.

bit k = 0 : the defects in the single Data Area DA[1+k+i∗8] may be registered in more than one DTB,

1 : all defects in Data Area DA[1+k+i∗8] are registered in MDTi/DTBk only (straight mapping).

Note: For Straight Mapping it is only relevant that all defects in a certain Data Area are registered in the related MDTi/DTBk. It is not relevant in which Spare Area the defect is actually reallocated.

Byte 16: Reserved: this byte is reserved and shall be set to 00h.

Byte 17..19: PBN of first Reallocation Entry

These 3 bytes shall be equal to the value of the PBN of Defective Block field of the first Reallocation Entry in this DTB. Bit 7..4 of byte 17 are reserved and shall be set to zero. If no Used Entries are defined in this DTB, then these bytes shall be set to FFFFFFh. See also chapter IV.5.1.2.

Byte 20: Reserved: this byte is reserved and shall be set to 00h.

Byte 21..23: PBN of last Reallocation Entry

These 3 bytes shall be equal to the value of the PBN of Defective Block field of the last Reallocation Entry in this DTB. Bit 7..4 of byte 21 are reserved and shall be set to zero. If no Used Entries are defined in this DTB, then these bytes shall be set to FFFFFFh. See also chapter IV.5.1.2.

Byte 24: Reserved: this byte is reserved and shall be set to 00h.

Byte 25..27: PBN of first Free Entry

These 3 bytes shall be equal to the value of the PBN of Replacement Block field of the first Free Entry in this DTB. Bit 7..4 of byte 25 are reserved and shall be set to zero. If no Free Entries are available in this DTB, then these bytes shall be set to FFFFFFh. See also chapter IV.5.1.2.

Byte 28: Reserved: this byte is reserved and shall be set to 00h.

Byte 29..31: PBN of last Free Entry

These 3 bytes shall be equal to the value of the PBN of Replacement Block field of the last Free Entry in this DTB. Bit 7..4 of byte 29 are reserved and shall be set to zero. If no Free Entries are available in this DTB, then these bytes shall be set to FFFFFFh. See also chapter IV.5.1.2.

Byte 32..1567: DT Entries

Each DT Entry consists of 6 bytes. The first three bytes indicate a defective Block and the last three bytes identify the Replacement Block that has been assigned. The 4 most significant bits of byte m and byte m+3 are used to indicate the status of the replacement.

Unused DT Entries

All bytes in the range 32..1567 not occupied by DT Entries shall be set to 00h.

Byte 1568..2047: Reserved: these 480 bytes are reserved and shall be set to 00h.

IV.5.1.1 Format of the DT Entries

Byte m		Byte m+1	Byte m+2
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Status 1	*PBN of Defective Block*		

Byte m+3		Byte m+4	Byte m+5
bit 7..4	bit 3..0	bit 7..0	bit 7..0
Status 2	*PBN of Replacement Block*		

The PBN of Defective Block field shall be equal to the PBN of the defective Block to be replaced.
The PBN of Replacement Block field shall be equal to the PBN of the Replacement Block assigned to hold the replaced Block. (The PBN of each Replacement Block in the Spare Areas shall occur exactly once in the Defect Table.)

Status 1	Status 2	Entry type	definition
0000b	00xx	Reallocation Entry	The entry identifies a valid replacement.
0001b	00x0	Reallocation Entry	The entry identifies a defective Block that has not been recorded at it's replacement address.
0010b	0000	Free Entry	The entry identifies a Replacement Block usable for future replacement, the PBN of Defective Block field shall be set to zero.
0011b	0000	Unusable Entry	The entry identifies a Replacement Block unusable for future replacement, the value of the PBN of Defective Block field is undefined.
others	others	--	Reserved

Status 2	definition
xxx0	The original location has been recorded with the same data as the replacement location or the original location contains the most recently written information.
xxx1	The original location may contain different data as the replacement location.
xx0x	The Defective Block specified in this Entry has been replaced as a single Block.
xx1x	The Defective Block specified in this Entry is part of a Packet that has been replaced as total Packet. All 32 replaced Blocks shall be in one replacement Packet. (see chapter IV.6.2)

There shall be no hierarchical replacements: no PBN of Defective Block field is allowed to contain the same value as any PBN of Replacement Block field.

IV.5.1.2 Sorting of the Defect Table

The DT Entries shall be sorted over the full Defect Table, starting in MDT0/DTB0, continued in MDT0/DTB1, etc., and ending in MDT7/DTB7.

In this sorting algorithm the Used Entries (with Status 1 = 0000b and 0001b) and the Free Entries (with Status 1 = 0010b) in each DTB shall be grouped and sorted in ascending order separately. The Unusable Entries (with Status 1 = 0011b) are grouped but need not to be sorted.

- Each DTB can contain all 3 types of entries. Within the DTB's the Used Entries shall be placed first, followed by the Free Entries and at last the Unusable Entries are placed.
- The Used Entries shall be sorted in order of their PBN of Defective Block field (ignoring the value of the Status 1 field).
- The Free Entries shall be sorted in order of their PBN of Replacement Block field (ignoring the value of the Status 2 field).

See Figure 11.

MDT	DTB	Status 1	PBN of Defective Block	Status 2	PBN of Replacement Block
0	0	0/1	0 05 A0	x	x xx xx
		0/1	0 06 75	x	x xx xx
		0/1	ascending values ⇓	x	x xx xx
		0/1	0 0F 75	x	x xx xx
		2	0 00 00	x	0 04 00
		2	0 00 00	x	0 04 01
		2	0 00 00	x	0 04 02
		2	0 00 00	x	ascending values ⇓
		2	0 00 00	x	0 04 FF
		3	x xx xx	x	0 04 23
		3	x xx xx	x	arbitrary order ⇓
		3	x xx xx	x	0 02 D5
	1	0/1	> 0 0F 75	x	x xx xx
		0/1	ascending values ⇓	x	x xx xx
		:	:	:	:
		2	0 00 00	x	> 0 04 FF
		2	0 00 00	x	ascending values ⇓
		:	:	:	:
		3	x xx xx	x	x xx xx
		:	:	:	:
	2	0/1	etc.	x	x xx xx
		:	:	:	:
		2	0 00 00	x	etc.
		:	:	:	:
		3	x xx xx	x	x xx xx
		:	:	:	:

Figure 11 Sorting of the Defect Table
(example)

IV.6 The Defect Management procedure

IV.6.1 Handling of the Defect Tables

At Initialization (see chapter V.2) an MDT is created, containing a DT Entry for each Replacement Block, with Status 1 = 0010b, the PBN of Defective Block field set to 00000h and Status 2 = 0000b (all Free Entries).
The Main Defect Table shall be updated by a recorder each time a defect is reallocated.
When the disc is ejected from a recorder, the Secondary Defect Table shall have the same contents as the Main Defect Table.

To achieve a consistent way of handling the Defect Table by different drives, the following procedure for handling the Defect Table is recommended:

- At initialization all Replacement Blocks of each Spare Area are registered in a separate DTB: MDTi/DTBk refers to the Replacement Blocks of SA[1+k+i∗8].
  So each DTB contains 256 Entries and some reserved space. If less than 64 SA's are available, the remaining DTB's shall be empty.
- All defects detected in Data Area DA[1+k+i∗8] are registered in MDTi/DTBk. So all defects are initially mapped to the closest SA towards the inside of the disc.
  As long as all defects in DA[1+k+i∗8] are registered in MDTi/DTBk only, this situation shall be indicated by the corresponding Straight Mapping flag bit (bit k of byte 15 in each DTB of MDTi).
- If all 256 replacements in one MDTi/DTBk have been used, a redistribution of the Entries over all or part of the DTB's can be done, whereby the one-to-one relation between a DA and a DTB can get lost (see Figure 12). In this case the corresponding Straight Mapping flag bit(s) shall be reset.
- The reserved space in the tables shall not be used.

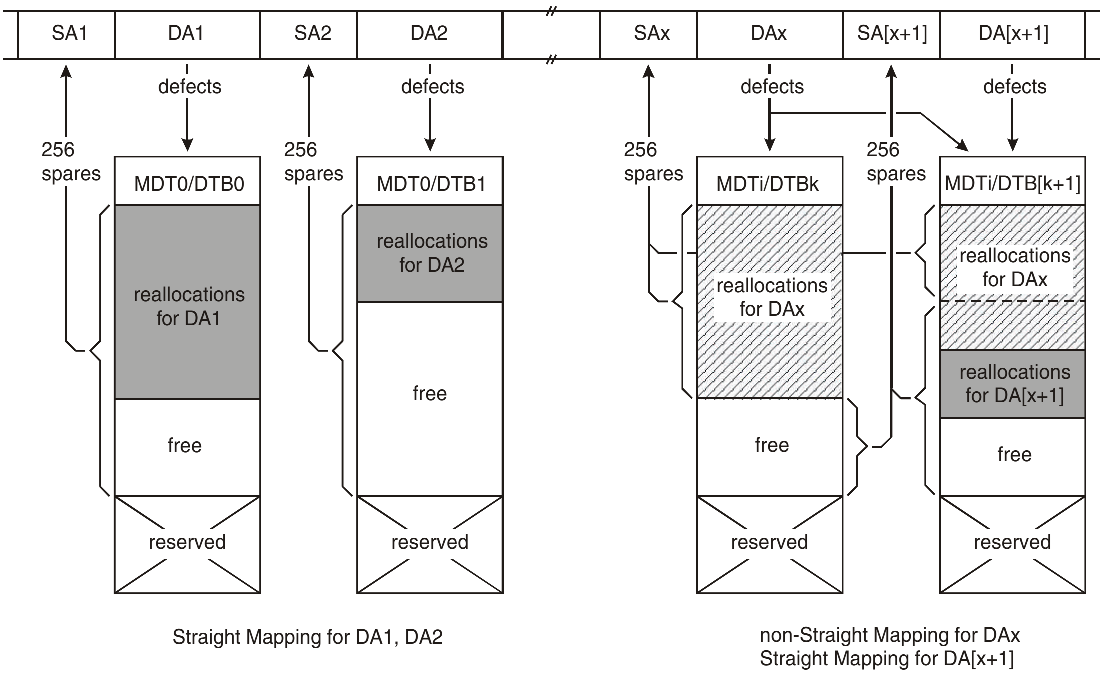

Figure 12 Example of Defect Table use

IV.6.2 Replacement of Blocks

If an error is detected in a Block during reading, the drive may replace the Block, mark the Block for replacement, or ignore the error for Defect Management. If the defective Block is to be replaced or marked for replacement, the drive shall assign a Replacement Block out of the set of Replacement Blocks with Status 1 = 0010b.

If the Block is replaced, then:
- the data from the original Block shall be recorded in the Block identified by the PBN of Replacement Block field,
- the Status 1 field of the DT Entry shall be set to 0000b, the Status 2 field shall be set accordingly,
- the Defect Table sort order shall be updated.

If the Block is being marked for later replacement, then:
- the Status 1 field of the DT Entry shall be set to 0001b,
- the Defect Table sort order shall be updated,
- future read requests shall be performed from the Block identified by the PBN of Defective Block field,
- future write requests shall be handled by writing to the Block identified by the PBN of Replacement Block field, changing the Status 1 field to 0000b, and updating the Defect Table sort order. The Status 2 field shall be set accordingly.

If a Replacement Block itself is found to be defective, it is indicated by Status 1 = 0011b. In this case the PBN of Defective Block field is undefined.

Optionally a complete Packet can be replaced. The replaced Packet then shall be copied into a single Packet of the Spare Area. Each Block of the replaced Packet shall be indicated in the Defect Tables separately. These Blocks shall be identified by the correct setting of Status 2 (bit 5).

IV.6.3 Handling of streaming data

In case of a “write_streaming” command, the drive shall remove all defects with Status 1 = 0000b within the written address range(s) from the Defect Tables or change them to Status 1 = 0001b.

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V Physical Formatting in Background

V.1 Introduction

The disc shall be considered fully physical formatted if the Lead-in Area, the maximally possible Program Area and the Lead-out Area have been recorded. During the Background Formatting process all blank areas in the Program Area of the disc will be recorded with Packets containing 2K Blocks with all user data bytes set to AAh.

The disc shall be considered partially physical formatted if at least the MIP & MDT's in the Lead-in Area have been recorded.

The status of the disc shall be indicated by the Disc Status in the MIP. If partially physical formatted, the Last Written Address shall be recorded in the LWA field in the MIP.

If compatibility with CD-ROM drives is required, the disc shall contain a Lead-in Area, a Lead-out Area, and a Program Area with no blank areas between the Lead-in and Lead-out Areas.

Physical formatting is the process to reach the status of CD-ROM compatibility. Physical formatting can be done in two different ways:

1) Pre-formatting, which is the conventional way of physical formatting used for many storage media. After the pre-formatting process, the disc is fully physical formatted. User data shall not be recorded to the disc until the pre-formatting process is complete.
This process generally consists of the following steps:
- writing the Lead-in Area,
- writing the Program Area,
- writing the Lead-out Area,
- verification of the Program Area and initialization of the Defect Management.

2) Background Formatting, which is a physical formatting process that runs in the background during use of the disc in a recorder. After the Background Formatting process has been completed, the disc is fully physical formatted. User data may be recorded to the disc during the Background Formatting process.
The Background Formatting process consists of the following steps:
- Initialization of the Defect Management
- De-icing of the Program Area
- Finalization of the Lead-in and Lead-out Areas
- Early-eject finishing (if applicable)
- Restarting the Background Formatting on an early-ejected disc
- Verification (optionally selected by host computer)

Because the Pre-formatting process may be rather time consuming, Background Formatting can be a much more time-efficient solution for the user of the disc. During the initialization phase of the Background Formatting process only a minimum amount of data will be recorded onto the disc, after which the disc can be used by the application. A disc on which a Background Formatting process is active, may be formatted further by the CD recorder in the background during the moments that the application is not accessing the disc.

V.2 Initialization of the Defect Management

When a blank disc is inserted into a recorder, an initialization procedure is started by the host computer. This initialization creates an MTA at the end of the Lead-in Area with a MIP and sufficient MDT's to define all Spare Areas. All addresses given in the MIP and MDT's shall refer to the final locations. The subcode in the MTA shall be set to values representing the fully physical formatted situation.
As a result of the initialization procedure the following disc will exist:

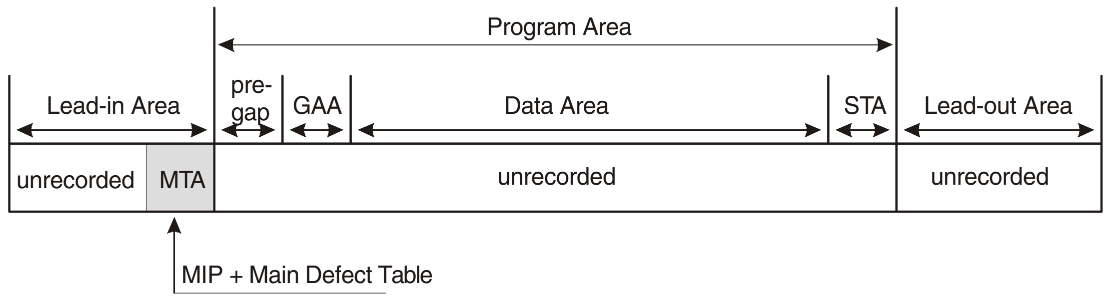

Figure 13 Status of the disc after initialization

Because of the very limited amount of data to be recorded, the initialization procedure will be finished just in seconds. The disc is now ready for data storage and can be released for use by the host computer.

In general, after the initialization, the host computer writes some initial File System Structures (FSS) to the disc. These File System Structures as well as the user data can be placed anywhere in the logically addressable space of the disc. In the following examples it is assumed that the disc is initially recorded sequentially.
The GAA can be recorded by the host computer at any time.

V.3 De-icing of the Program Area

De-icing is the process of recording all Packets in the Program Area of the disc. During the De-icing phase, blank areas shall be filled with Packets containing 2K Blocks with all AAh bytes or with user data when requested. The pre-gap shall be filled with TDB's according to the CD-RW System Description. The De-icing shall be performed by the drive itself, without interaction with the host computer.

During the time intervals when the drive is idle, the De-icing process can proceed in the background. When the host computer requests disc access, the De-icing process is suspended and the control of the disc is returned to the host.
Host requested writes in blank areas shall be registered by the drive and shall not be overwritten by the De-icing process.
The drive shall keep track of all areas that have been recorded or De-iced.
Every time after de-icing about 800 Packets (≈ 50 Mbytes), the LWA field in the MIP should be updated. This reduces the recovery time in case of power failures during Background Formatting.

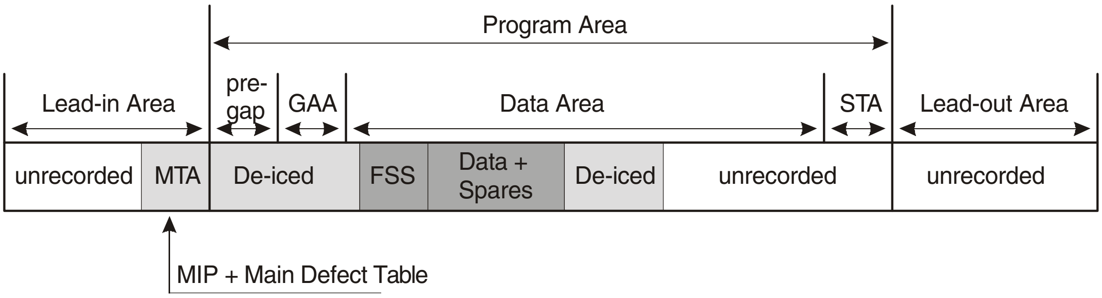

Figure 14 Example status of the disc after some De-icing and recording

V.4 Finalization of the Lead-in and Lead-out Areas

After the full Program Area has been recorded or De-iced, the Lead-in and Lead-out Area are recorded. To be able to interrupt the recording of the Lead-in and the Lead-out Area on write/read requests from the host computer, the Lead-in Area as well as the Lead-out Area are written in variable Packet size. The Lead-in and Lead-out Areas should be recorded continuously until the moment of an interrupt request, after which the recording shall stop by writing a Packet end (2 Run-out Blocks and a partial Link Block). After the action requested by the host has been finished, writing to the Lead-in or Lead-out is resumed with a Packet start (partial Link Block and 4 Run-in Blocks) followed by User Data Blocks. To prevent too much fragmentation in the Lead-in and Lead-out Area, each Packet shall have a size of at least 128 User Data Blocks.

The time code in the subcode shall be continuous and synchronized to the ATIP time code according to the CD-RW System Description.
Inside the Packets, the TOC in the subcode shall be continuous and according to the CD-RW System Description. Crossing Packet boundaries, the TOC does not need to be contiguous.

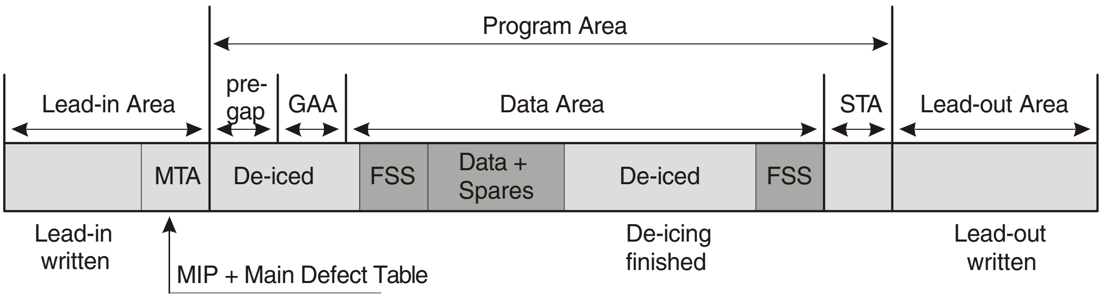

Figure 15 Example status of the disc after finalization

At the end of the finalization process the host computer can update the File System Structures and create additional File System Structures if needed.

V.5 Eject

Before the disc is ejected from the recorder, the contents of the MTA Packets shall be copied to the STA Packets.

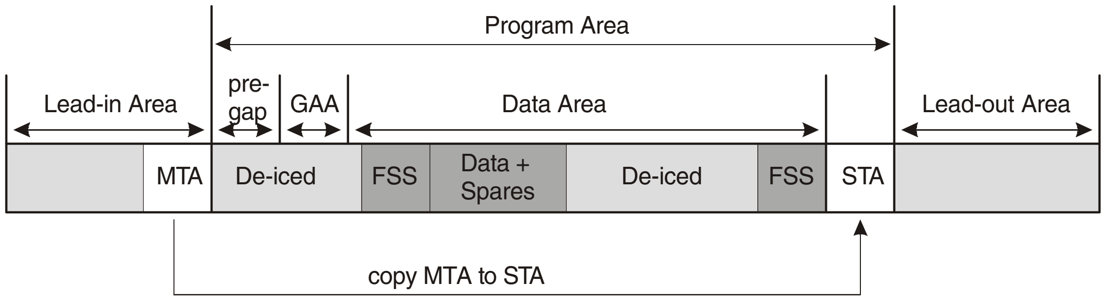

Figure 16 Example of final status of the disc

V.6 Early-eject finishing

When the user pushes the eject button of the drive, he expects the disc to come out in the shortest possible time. However he also expects that the disc is “ROM-compatible”. This means that the disc shall have at least a Lead-in and a Lead-out Area and no blank areas in the Program Area.

If the Background Formatting process is not yet finished, the drive may decide to finish the De-icing and finalization processes in the normal way.
If the remaining physical formatting will take much time to finish, the drive may decide to finish the disc in a ROM-compatible way, for which the following steps are needed (see Figure 17):

Drive actions to finish running tasks:
1) Pending write/read requests from the computer shall be completed.

Drive actions to finalize the disc:
2) The active background De-icing process shall be stopped.
3) If recordings have been made in blank areas, all blank areas up to the last recorded Packet shall be De-iced.
   If the written area ends with an SA, this SA shall have a size of 8 Packets.
4) A temporary STA shall be recorded immediately following the last written Packet. The SDT’s in the temporary STA shall contain the same information as the corresponding MDT’s. The SIP shall have the same information as the MIP; in both the SIP and the MIP the addresses of the SDTj locations shall point to the temporary locations of the SDT’s. (At restart of the Background Formatting these pointers in the MIP shall be reset to their normal addresses in the final STA.)
   The LWA recorded in the LWA field in both the MIP and SIP shall be set to the first PBN of the temporary SIP Packet.
5) A temporary Lead-out Area of at least 30 seconds shall be recorded.
6) The Lead-in Area, with subcode data according to the actual situation of the disc, shall be recorded.
7) The MTA in the Lead-in Area shall be rewritten with adapted subcode data reflecting the actual situation of the disc.

Host actions:
8) If not previously completed, the Host computer shall write the GAA.
9) The host computer issues an “eject disc” command.

Drive actions to eject the disc:

10) The drive shall flush it's cache.
11) The drive ejects the disc.

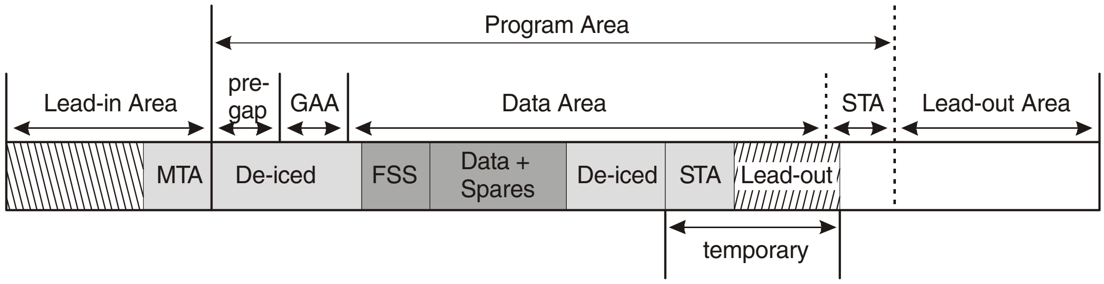

Figure 17 Early-eject status of the disc

V.7 Restarting the Background Formatting on an early-ejected disc

When an early-ejected disc is re-inserted into a recorder, this device will detect the "partially physical formatted" status and the host computer can initiate the continuation of the Background Formatting. De-icing shall restart from the position indicated by the LWA pointer (see Figure 18), thus starts overwriting the temporary Lead-out Area. It will proceed until the full disc has been De-iced/finalized.

The temporary STA is considered as being physical formatted. New write requests are allowed to overwrite the temporary STA, which area thereby is lost. Therefore the addresses of the SDTj locations in the MIP shall be reset to the normal addresses of the SDTj locations in the final STA.

Before a next eject the drive shall update the subcode data in the Lead-in Area (including the MTA).

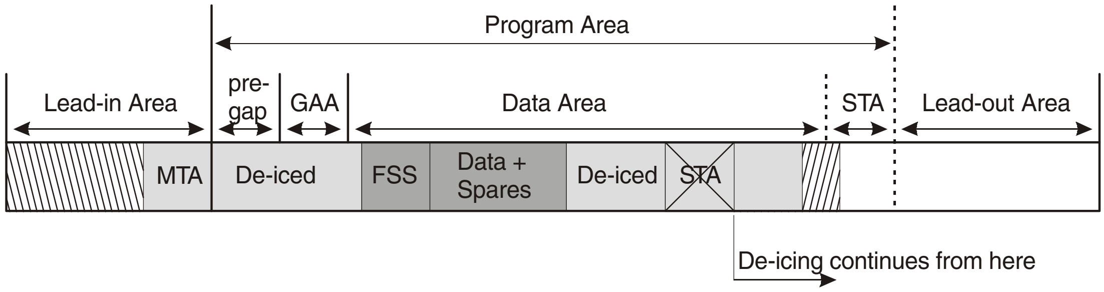

Figure 18 Status of an Early-ejected disc after restarting De-icing

V.7.1 Automatic Background Formatting restart

The Background Formatting and Verification, if indicated accordingly by the Disc Status bits in the MIP/SIP, shall automatically restart when a write is requested with an LBN beyond the currently De-iced area. The Background Formatting shall be restarted prior to the processing of the write command.

V.8 Verification

Verification is the process of reading and checking Blocks in the Program Area of the disc. If the Verification process is interrupted, the Verification status bit in byte 24 shall be set to 1 and the Last Verified Address (LVA) shall be recorded in the LVA fields in the MIP/SIP.

After a disc has been physical formatted,
1) it shall be verified if so selected by the host via certification, or
2) it can be verified optionally.
The disc can also be verified at a later stage when there are doubts about the quality of the recordings on the disc.

If a Block is found unreliable, the PBN of that Block, together with the PBN of a Replacement Block can be added to the Defect Table. The user data in the defective Block should be copied to the new location as indicated by the Defect Table.

V.9 Requirements for writing in Blank or Non-verified Areas

This chapter gives an overview of the behaviour of the drive in case of write requests to Blank or Non-verified areas on a disc where the Background Formatting process is active.
If a write error is detected or the verify fails, the drive shall use or create the Spare Areas as defined in this DM&PF document.

V.9.1 Blank discs

If the host computer requests writing in a blank area, then (see chapter V.3):
- the drive shall verify the recorded area if the host has directed the Background Formatting to also do a certification,
- the drive shall register the recorded area,
- de-icing shall not overwrite the recorded area.

V.9.2 Used discs compliant with this DM&PF

If the host computer requests writing in a blank or non-verified area, then (see chapter VI.3.1):
- the drive shall verify the recorded area autonomously,
- if the recorded area is in a blank area then the drive shall register the recorded area,
- de-icing shall not overwrite the recorded area.

V.9.3 Used discs not compliant with this DM&PF

If the host computer requests writing in a blank or non-reformatted (= de-iced) or non-verified area, then (see chapter VI.3.2):
- the drive shall verify the recorded area autonomously,
- if the recorded area is in a blank or non-reformatted area the drive shall register the recorded area,
- de-icing shall not overwrite the recorded area.

VI Annexes

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VI.1 How to achieve Defect Management and File System compatibility

This annex gives some guidelines how to achieve (read)compatibility of CD-MRW discs according to this DM&PF with drives not compliant with this specifications.
To reach such compatibility, the drive has to understand Method 3 addressing and shall apply Defect Management (DM) remapping.

Another complication, which is not directly related to CD-MRW, might be that the host computer does not understand the applied File System. A recommendation for this case is given in annex VI.1.2

VI.1.1 Use of General Application Area (GAA) to achieve addressing and DM compatibility

The newly introduced Method 3 addressing prevents non-CD-MRW-compliant drives from reading data from a CD-MRW disc. Because such a non-compliant drive does not apply Defect Management, this data could have been corrupted data.

The following Figure 19 shows a schematic representation of an example of the use of the GAA. Drives not compliant with the CD-MRW Method 3 addressing will find the ISO 9660 structure at PBN 16 in the GAA. This can point to a small piece of software, displaying a message with the URL address where the user can find drivers to make his non-compliant drive "read-compatible" with this DM&PF. The ISO 9660 structure at least shall have a "Read-me.txt" file with the content defined in annex VI.1.1.1 .

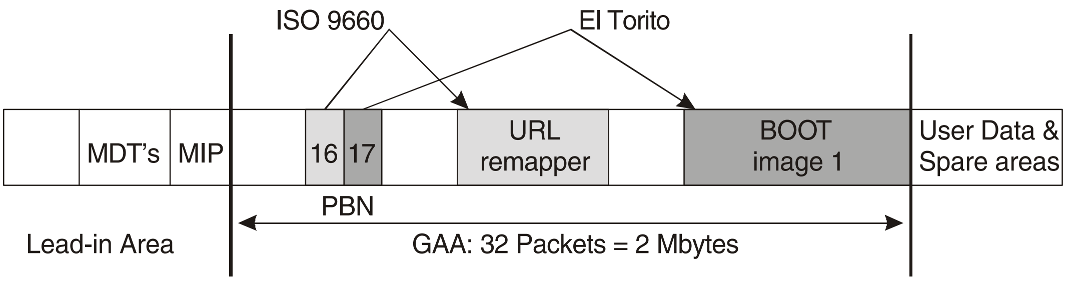

Figure 19 Example of the use of the GAA for achieving DM&PF compatibility

VI.1.1.1 Contents of Read-me.txt file

The Read-me.txt file shall have the following contents in ISO 646 format:
<start of text>

> This document is defined in size and content by the Mt. Rainier technical group, for the support of the CD-MRW format. You are seeing this document, instead of the advertised contents of this disc because your system is not supporting the CD-MRW format.
>
> If you have a system manufactured before 2002, you will need to contact your PC system or operating system manufacturer for appropriate software to read this format. Links to supporting software vendors can be found at: www.mt-rainier.org.
>
> If your systems optical drive carries the CD-MRW logo, and you are seeing this content, please contact your PC system, or optical drive manufacturer directly.
>
> The Mt. Rainier Group

<end of text>

VI.1.2 Use of ISO 9660 structures in the Data Area to achieve File System compatibility

The CD-MRW format is File System independent. It offers the host computer a linear addressing space over all it's Data Areas identified by LBN's.
However if the File System on the disc is not supported by the host computer, the host will not be able to retrieve the data files on the disc identified by their names, although the system could read data blocks identified by their LBN's.
Because all CD-ROM compatible systems understand the ISO 9660 File System, this particular system can be used to alert the user about possibly missing support on his computer for the specific File System applied to store data files on the disc.

The following Figure 20 shows a schematic representation of an example of the use of the ISO 9660 structure to achieve File System compatibility on systems that already can handle Method 3 addressing and Defect Management. If a system is not compliant with the actual File System applied on the disc, it will find the ISO 9660 structure at LBN 16.
This can point to a small piece of software, displaying a message with the URL address where the user can find a File System (FS) reader to make his non-compliant system "read-compatible" with the specific File System applied on the disc.

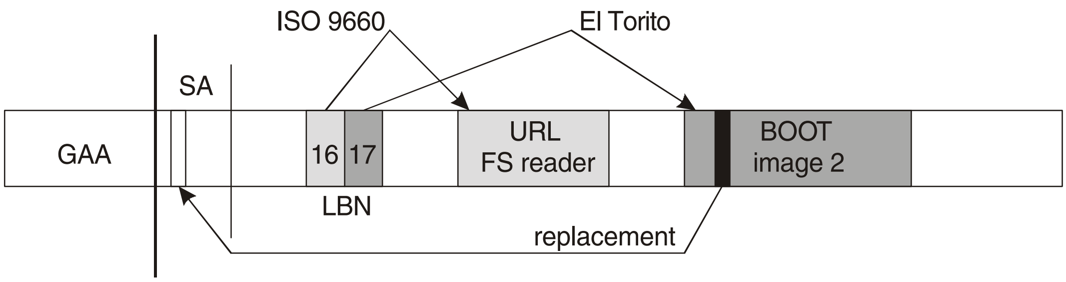

Figure 20 Example how to achieve File System compatibility

VI.1.3 Booting from a CD-MRW disc

As an option the disc can contain an "El Torito" boot image in the GAA and/or in the User Data Area.

VI.2 Recognition of discs according to the DM&PF specifications

The following flowchart shows how discs according to this DM&PF can be recognized and how they should be handled by recorders in certain error situations.

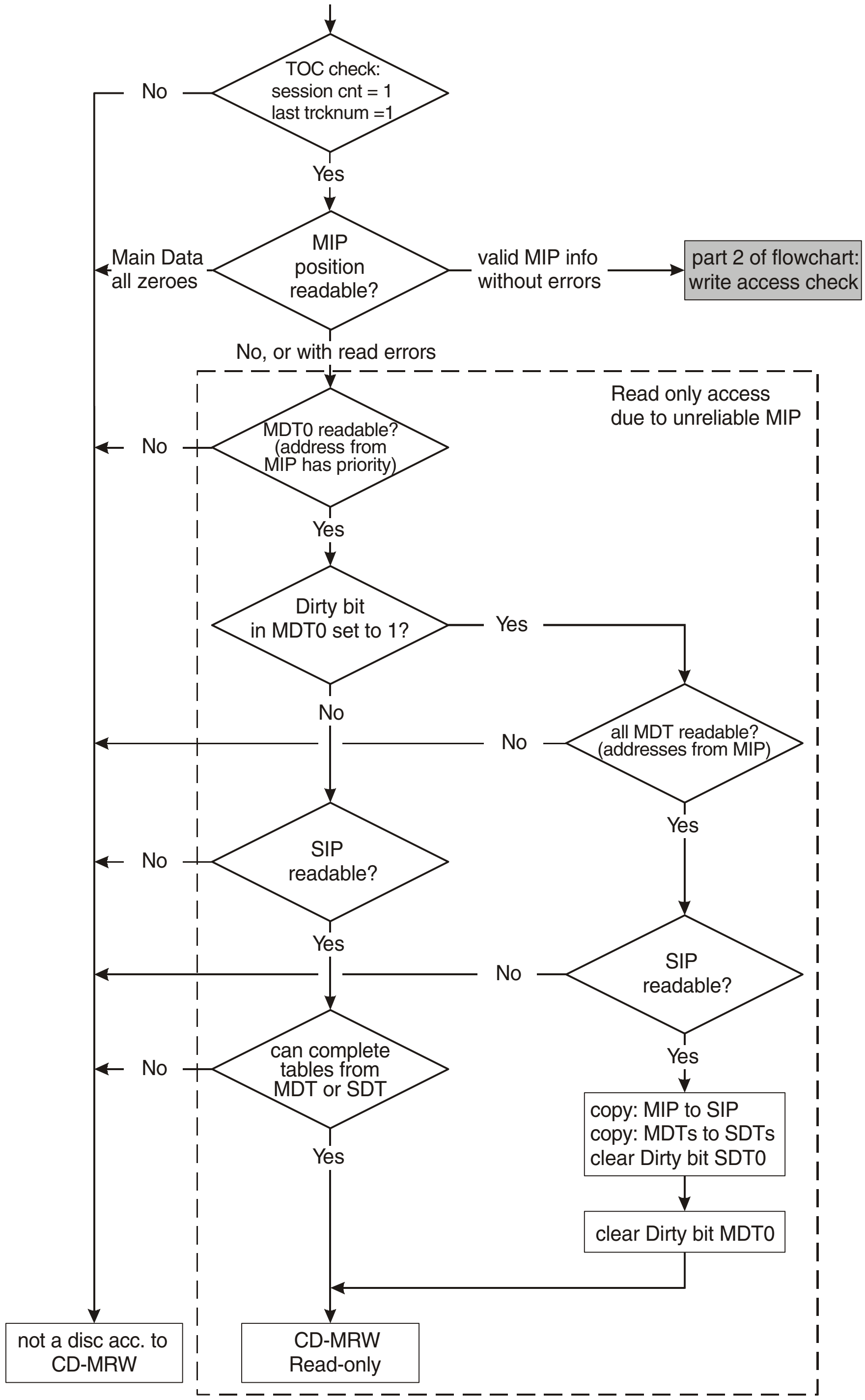

Figure 21 How to check a disc, part 1

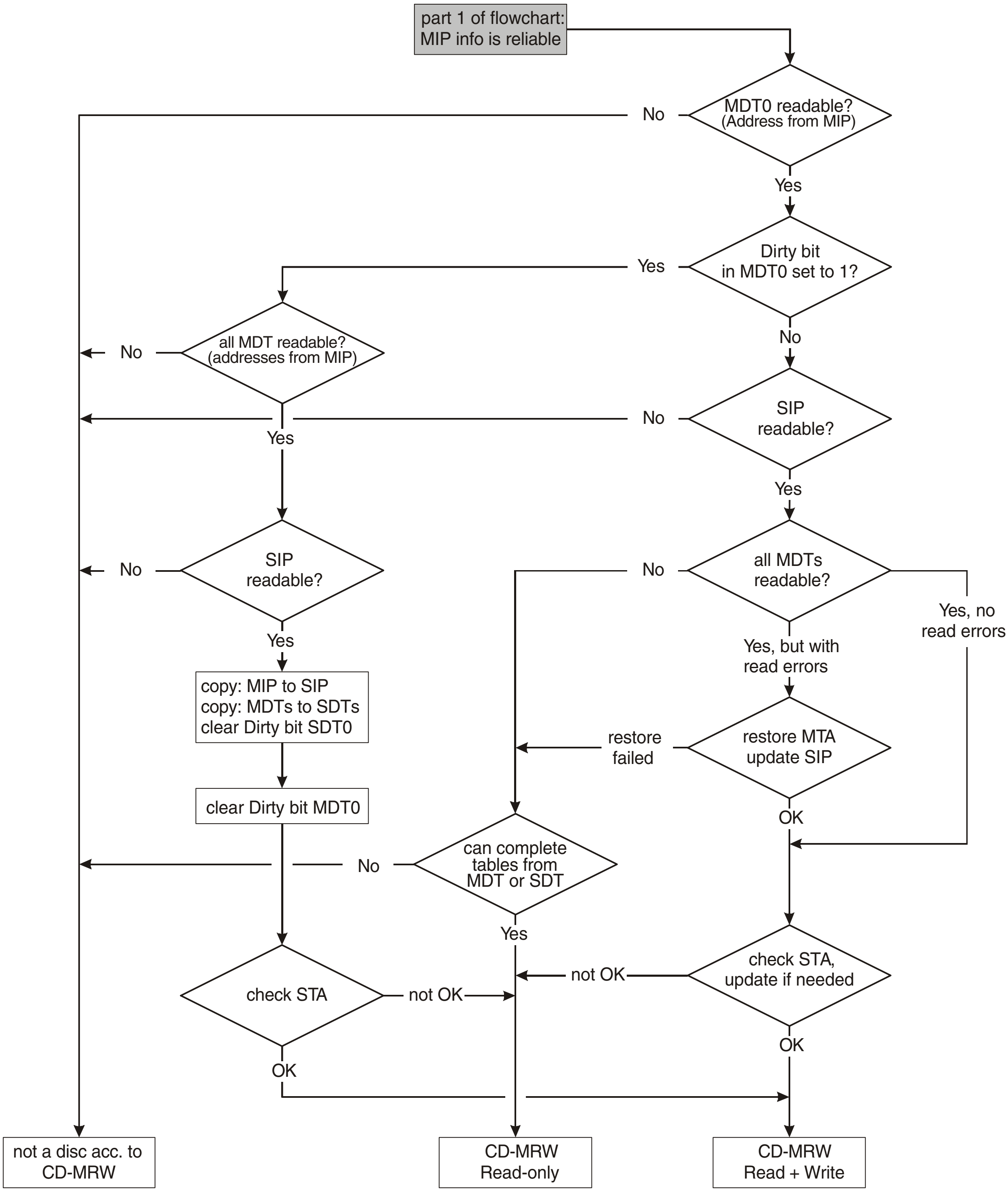

Figure 22 How to check a disc, part 2

VI.3 How to handle pre-formatted or used discs

VI.3.1 Reformatting discs compliant with this DM&PF

Discs formatted according to this DM&PF can be reformatted in the following way:

1) when the disc was previously fully formatted:
   - no de-icing needs to be applied. Instead of this a verification process will be executed in background.
   - write commands to a disc area that has not yet been verified, shall be followed by a verify.
   - the tracking of the process shall be stored in the LVA field in the MIP/SIP.
   - the Lead-in and Lead-out areas shall be rewritten.

2) when the disc was previously partially formatted:
   - the part already formatted needs no de-icing. Instead of this a verification process will be executed in background.
   - the remainder of the disc shall be de-iced and verified after de-icing.
   - write commands to a disc area that has not yet been verified or de-iced, shall be followed by a verify.
   - the tracking of the process shall be stored in the LWA and LVA fields in the MIP/SIP.
   - the Lead-in and Lead-out areas shall be rewritten.

VI.3.2 Formatting other used discs

Discs that have been used for data (or audio) formats other than this DM&PF, shall be formatted according to the normal rules for blank discs, with the following exceptions:
- de-icing overwrites the whole disc with Packets. After de-icing the Packets shall be verified.
- every write in the Program Area or in the Lead-in Area shall be followed by a verify.
- the tracking of the process shall be stored in the LWA and LVA fields in the MIP/SIP.
- the Lead-in and Lead-out areas shall be rewritten.

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VII List of changes

Differences between
CD-MRW, Defect Management & Physical Formatting, version 1.2, June, 2004
and CD-MRW, Defect Management & Physical Formatting, version 1.1, August, 2001

Main Technical changes:
- limitation of number of Defect Table Entries to prevent compatibility problems between different drives,
- adaptation of SIP/MIP contents at Early-eject according to existing implementations.

page	version 1.2	version 1.1	remarks
III-1	*Note: It is not allowed to end with an SA of less than 8 Packets. In this case the start of the actual Lead-out Area shall be set to a lower time code value (less than the maximum indicated in ATIP) such to adapt the nett capacity of the disc.*	*Note: It is not allowed to end with an SA of less than 8 Packets. In this case the start of the actual Lead-out Area has to be put forward to adapt the nett capacity of the disc.*	clarification
IV-7	**Figure 10** 32+(n-1)∗6 │ DT Entry n (n≤256) │ 6	**Figure 10** 32+(n-1)∗6 │ DT Entry n (n≤336) │ 6	consistency of implementations
IV-7	**Figure 10** 32+n∗6 │ Unused DT Entries (all bytes 00h) │ 1536-n∗6	**Figure 10** 32+n∗6 │ Unused DT Entries (all bytes 00h) │ 2016-n∗6	consistency of implementations
IV-7	**Figure 10** 1568 │ Reserved │ 480	---	consistency of implementations
IV-8	**Byte 8..9: Number of DT Entries** These 2 bytes shall indicate the total number of entries n in this DTB (0 ≤ n ≤ 256).	**Byte 8..9: Number of DT Entries** These 2 bytes shall indicate the total number of entries n in this DTB (0 ≤ n ≤ 336).	consistency of implementations
IV-9	**Byte 32..1567: DT Entries** ... All bytes in the range 32..1567 not occupied by DT Entries shall be set to 00h.	**Byte 32..2047: DT Entries** ... All bytes in the range 32..2047 not occupied by DT Entries shall be set to 00h.	consistency of implementations
IV-9	**Byte 1568..2047: Reserved:** these 480 bytes are reserved and shall be set to 00h.	---	consistency of implementations
IV-10	**IV.5.1.1 Format of the DT Entries**	---	adapted chapter lay-out

page	version 1.2	version 1.1	remarks
IV-10	(The PBN of each Replacement Block in the Spare Areas shall occur exactly once in the Defect Table.)	---	clarification
IV-12	So each DTB contains 256 Entries and some reserved space.	So each DTB contains 256 Entries and some empty space.	consistency of implementations
IV-12	The reserved space in the tables shall not be used.	The empty space of 80 entries in the tables should be retained.	consistency of implementations
IV-12	**Figure 12** Reserved	**Figure 12** 80 empty entries	consistency of implementations
IV-13	**IV.6.3 Handling of streaming data** In case of a “write_streaming” command, the drive shall remove all defects with Status 1 = 0000b within the written address range(s) from the Defect Tables or change them to Status 1 = 0001b.	(*moved from page IV-10*) In case of a “write_streaming” command, the drive shall remove all defects with Status 1 = 0000b within the written address range(s) from the Defect Tables or change them to Status 1 = 0001b.	adapted chapter lay-out
V-4	4) ... The SIP shall have the same information as the MIP; in both the SIP and the MIP the addresses of the SDTj locations shall point to the temporary locations of the SDT’s. (At restart of the Background Formatting these pointers in the MIP shall be reset to their normal addresses in the final STA.) ...	3) ... The SIP shall have the same information as the MIP, except for the SDTj locations, which shall point to the temporary locations of the SDT’s. --- ...	improvement
V-5	The temporary STA is considered as being physical formatted. New write requests are allowed to overwrite the temporary STA, which area thereby is lost. Therefore the addresses of the SDTj locations in the MIP shall be reset to the normal addresses of the SDTj locations in the final STA.	The temporary STA is considered as being physical formatted. New write requests are allowed to overwrite the temporary STA.	improvement

